Five things to know about Dark Matter

Alan Robinson

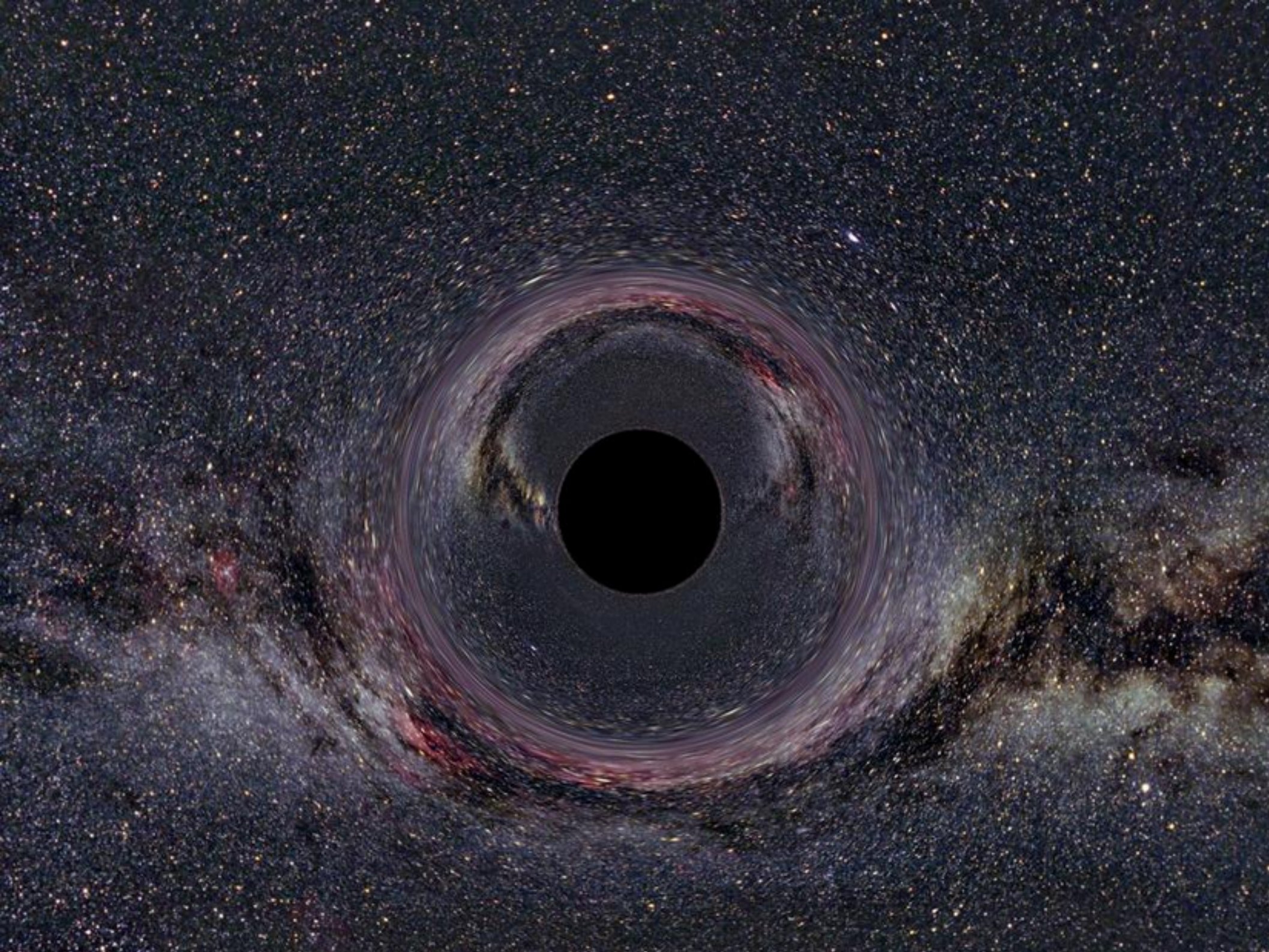
Nov 9, 2016
Fermilab Ask-a-Scientist

Five things to know about

Dark Matter

Dark

- Does not affect light

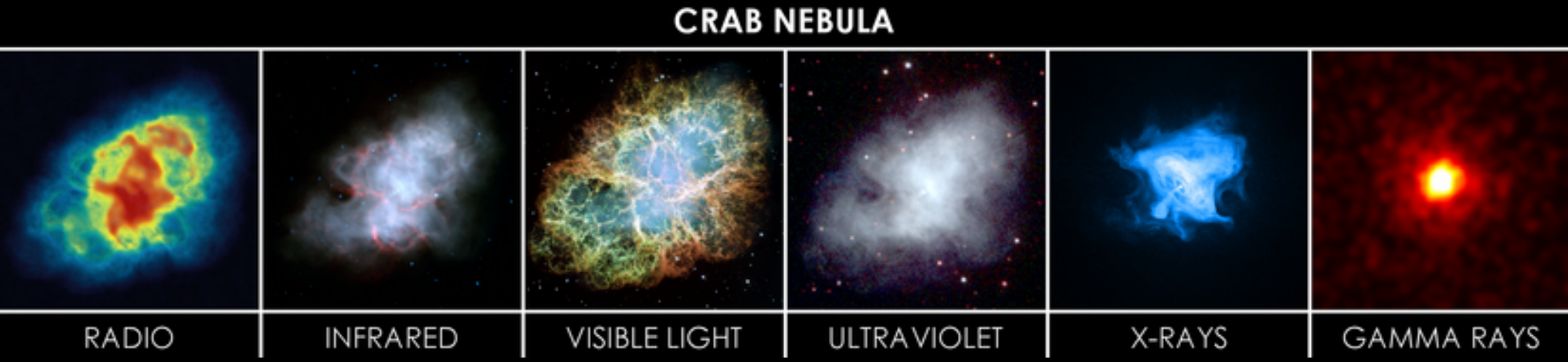


Dark

- Does not affect light
  - Does not absorb light

~~black~~

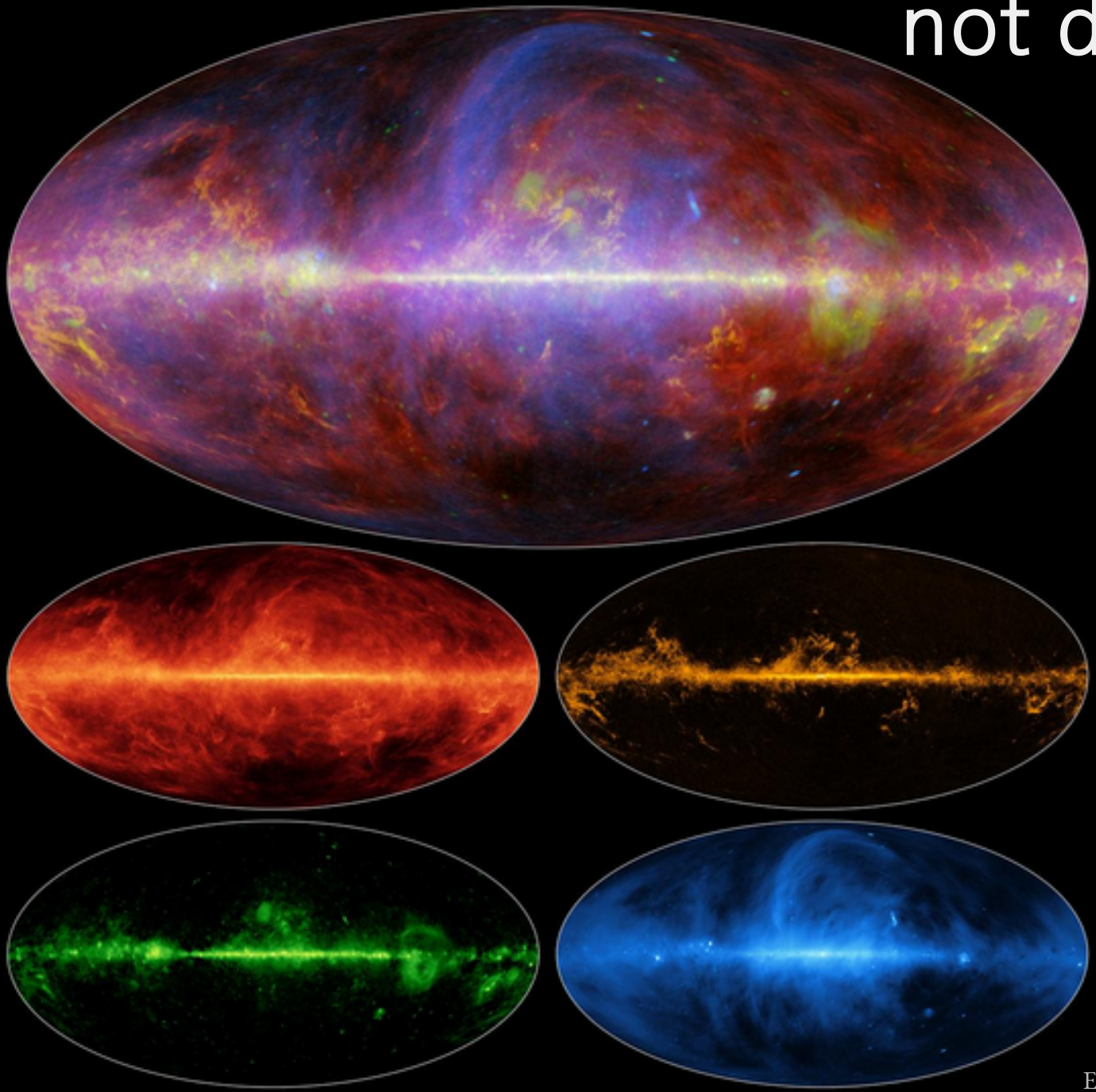
Interstellar and intergalactic dust does absorb light



The absorbtion changes with the wavelength of light, and depends on where you look

Dust in the Milky Way

not dark matter



ESA/NASA/JPL-Caltech

Dark

- Does not affect light
  - Does not absorb light

    ~~black~~
  - Does not refract light

    ~~transparent~~


We can see the earliest galaxies …
NASA Hubble Deep Field

We can see the earliest galaxies …

undistored by the Milky Way's dark matter

NASA Hubble Deep Field

Dark

- Does not affect light
  - Does not absorb light

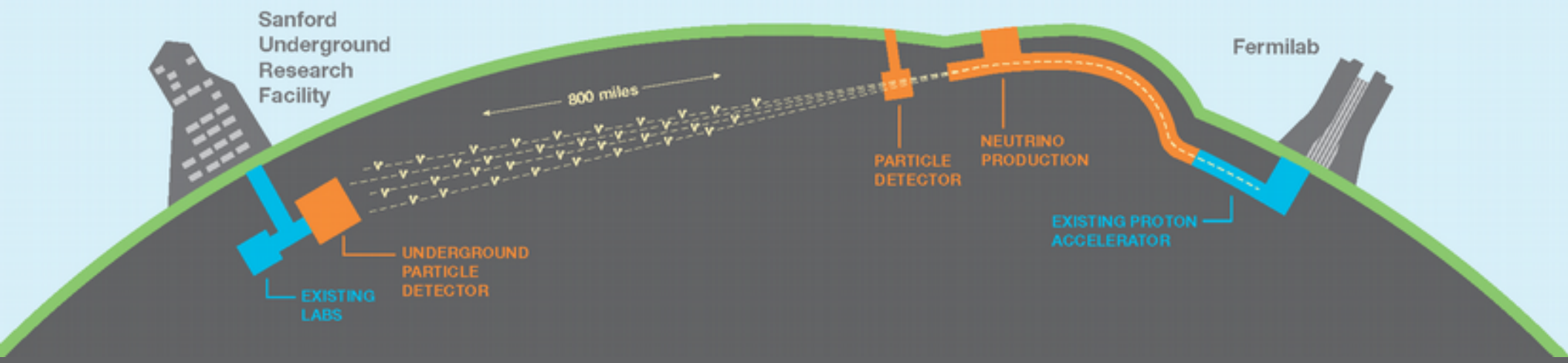
    ~~black~~
  - Does not refract light

    ~~transparent~~
  - Does not create light

Dark

- Does not affect light
  - Does not absorb light
    ~~black~~
  - Does not refract light
    ~~transparent~~
  - Does not create light
  - Electrically neutral

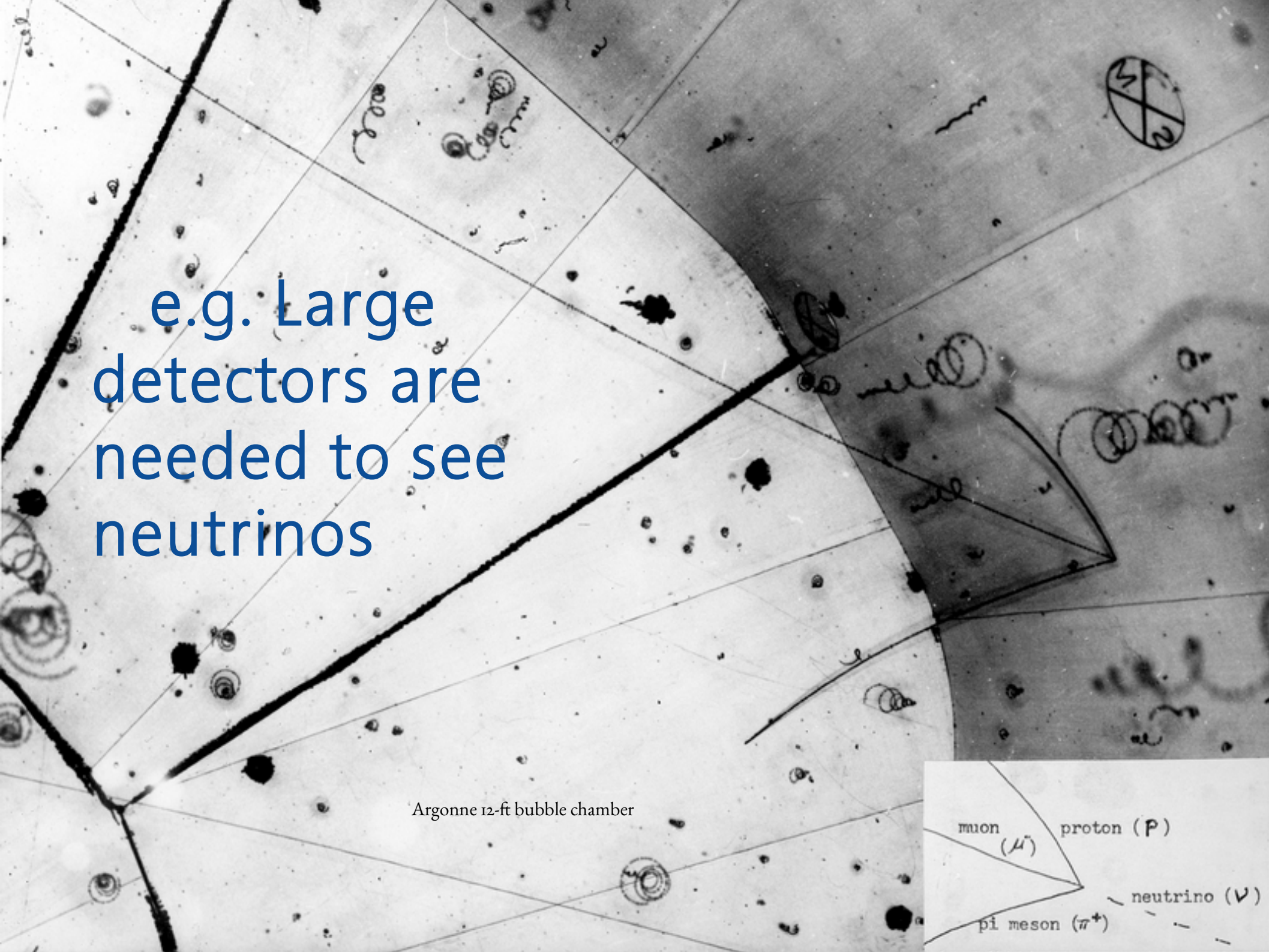
Long baseline neutrino facility



Electrically neutral particles pass through matter without stopping

Neutral particles are hard to detect

e.g. Large detectors are needed to see neutrinos



Argonne 12-ft bubble chamber


We’re building large dark matter detectors
DEAP-3600 collaboration

Five things to know about Dark Matter

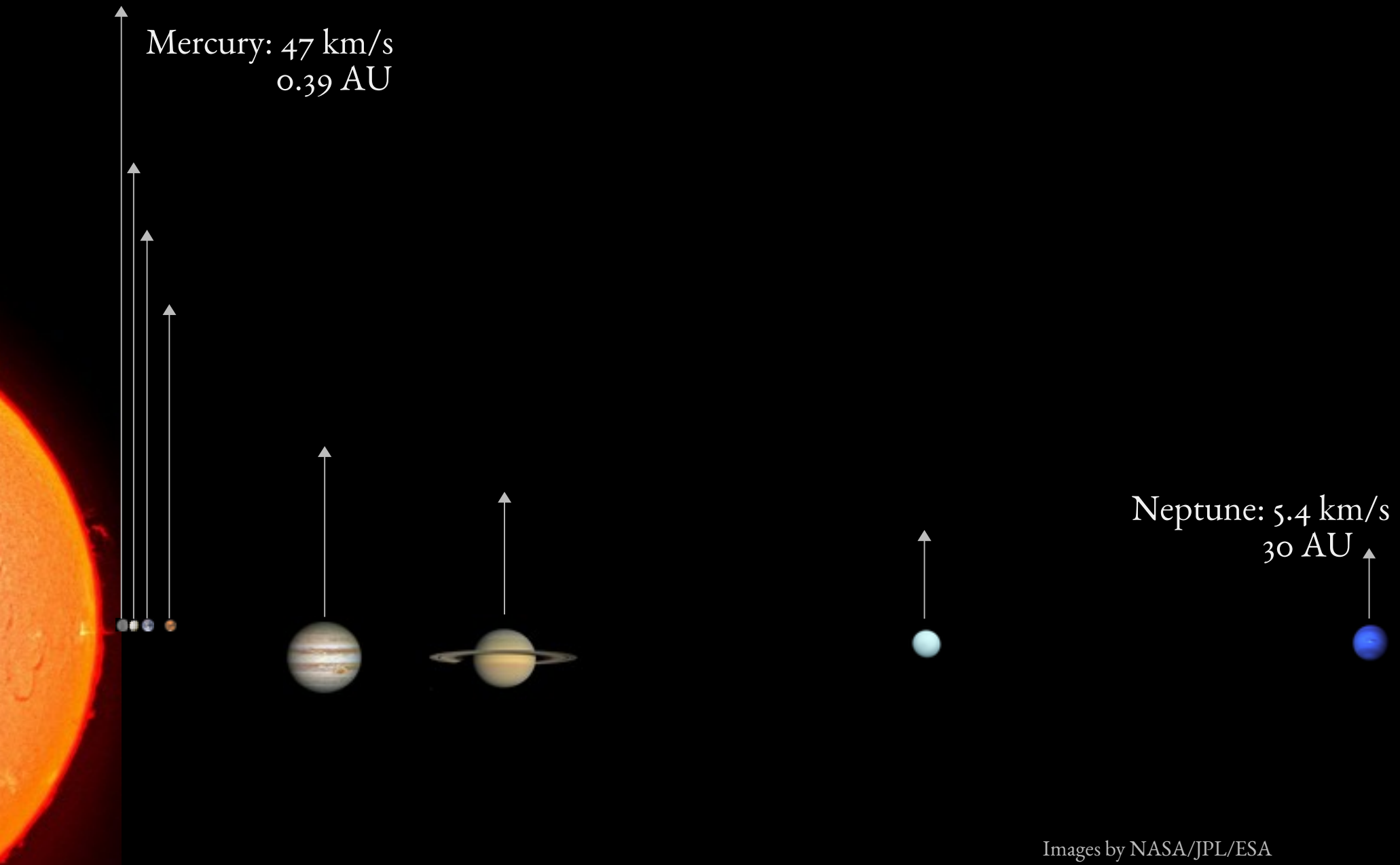
Five things to know about

Dark Matter

Matter

- Dark matter has mass

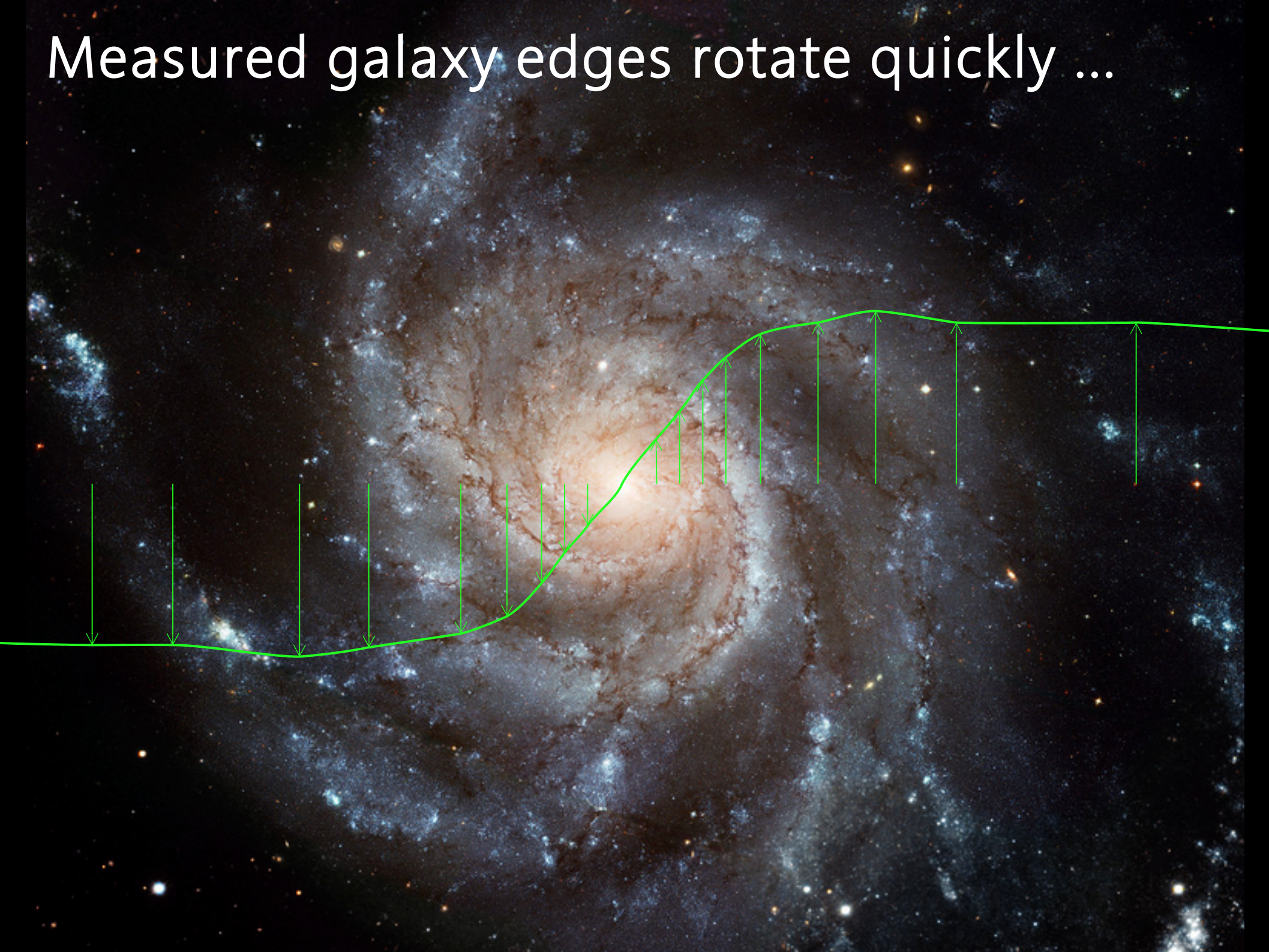
Planets revolve more slowly the farther they are from the massive sun



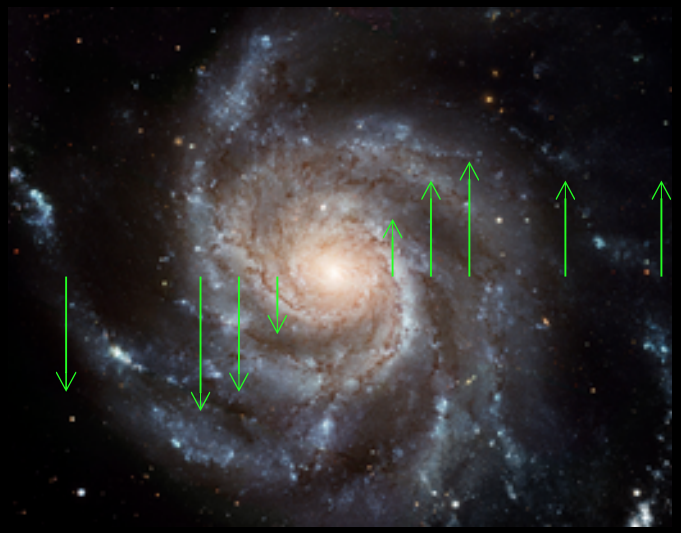
Images by NASA/JPL/ESA

If only stars and dust made galaxies,
they would rotate like this

Measured galaxy edges rotate quickly ...



the galaxy's dark matter is much larger than its stars in size and mass



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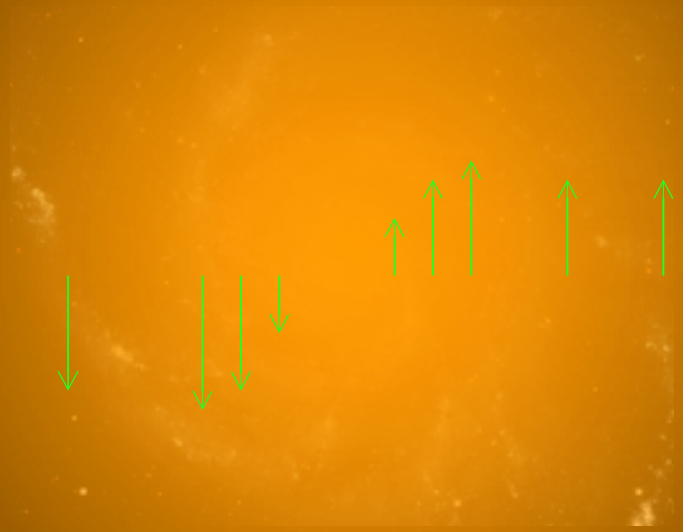
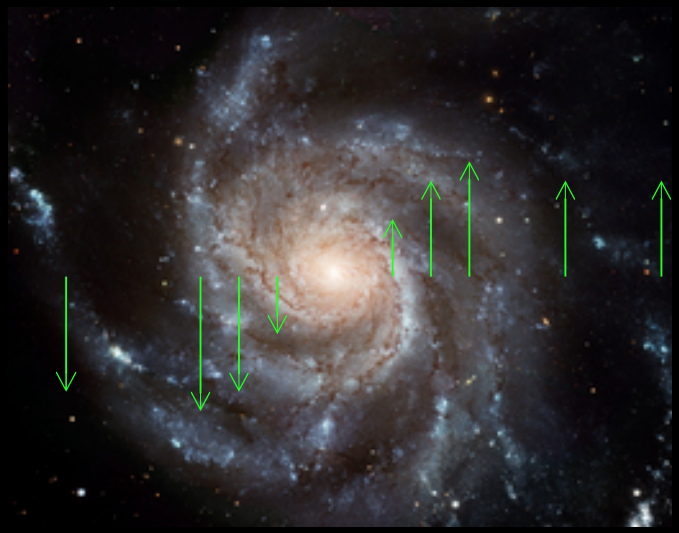


galactic rotation shows the hidden dark matter



galactic rotation shows
the hidden dark matter

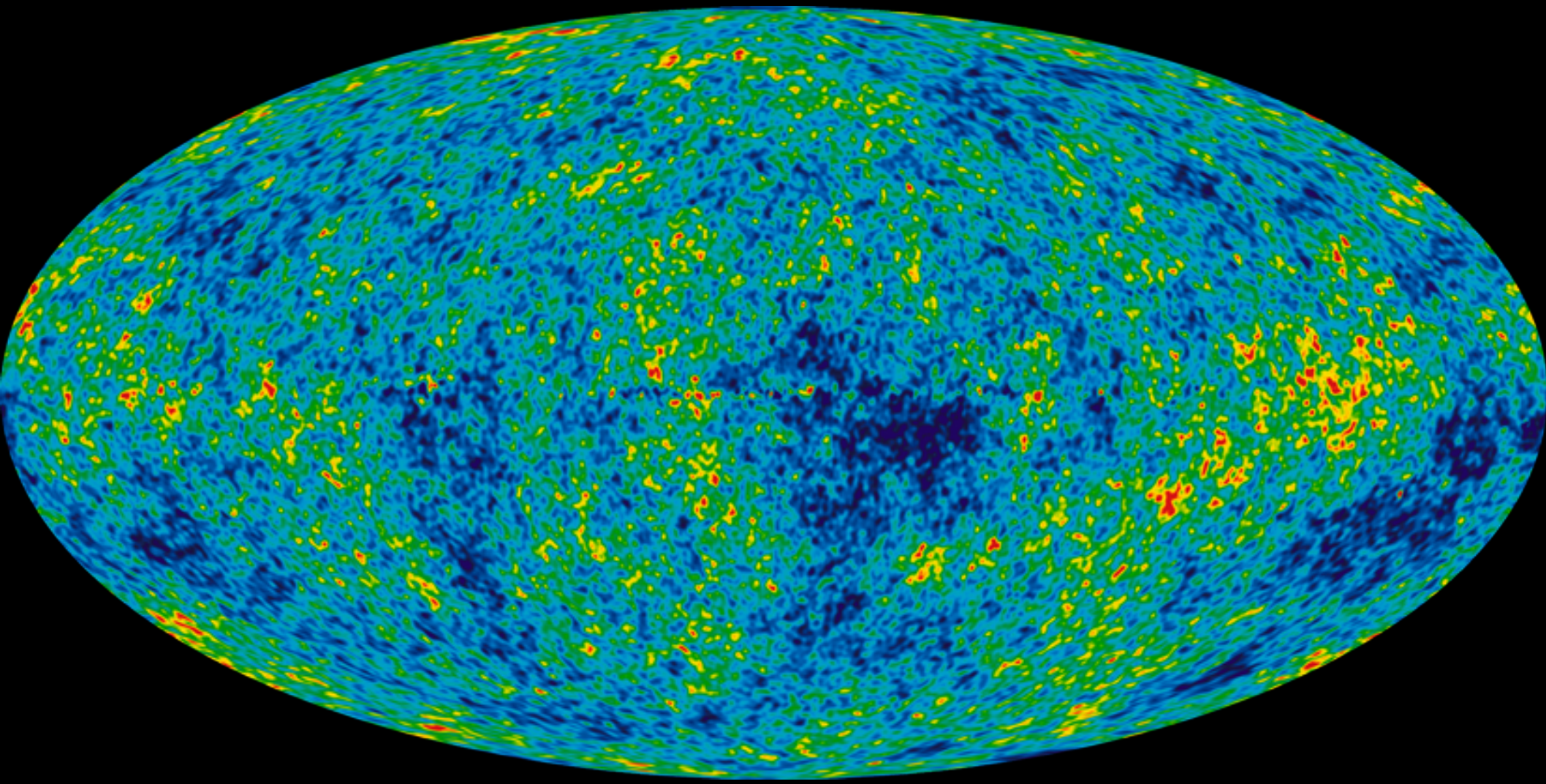
Matter

- Has mass
  - ×6 more mass than visible stars and dust
  - Seen with
    - Galactic rotation
    - Gravitational lensing
    - Big Bang
- Must be radioactively stable

Gravitational Lensing

How light from distant galaxies bends as it passes closer galaxies depends on the galaxy mass.

The size and shape of ripples in the early universe depends (among other things) on how much dark matter is present



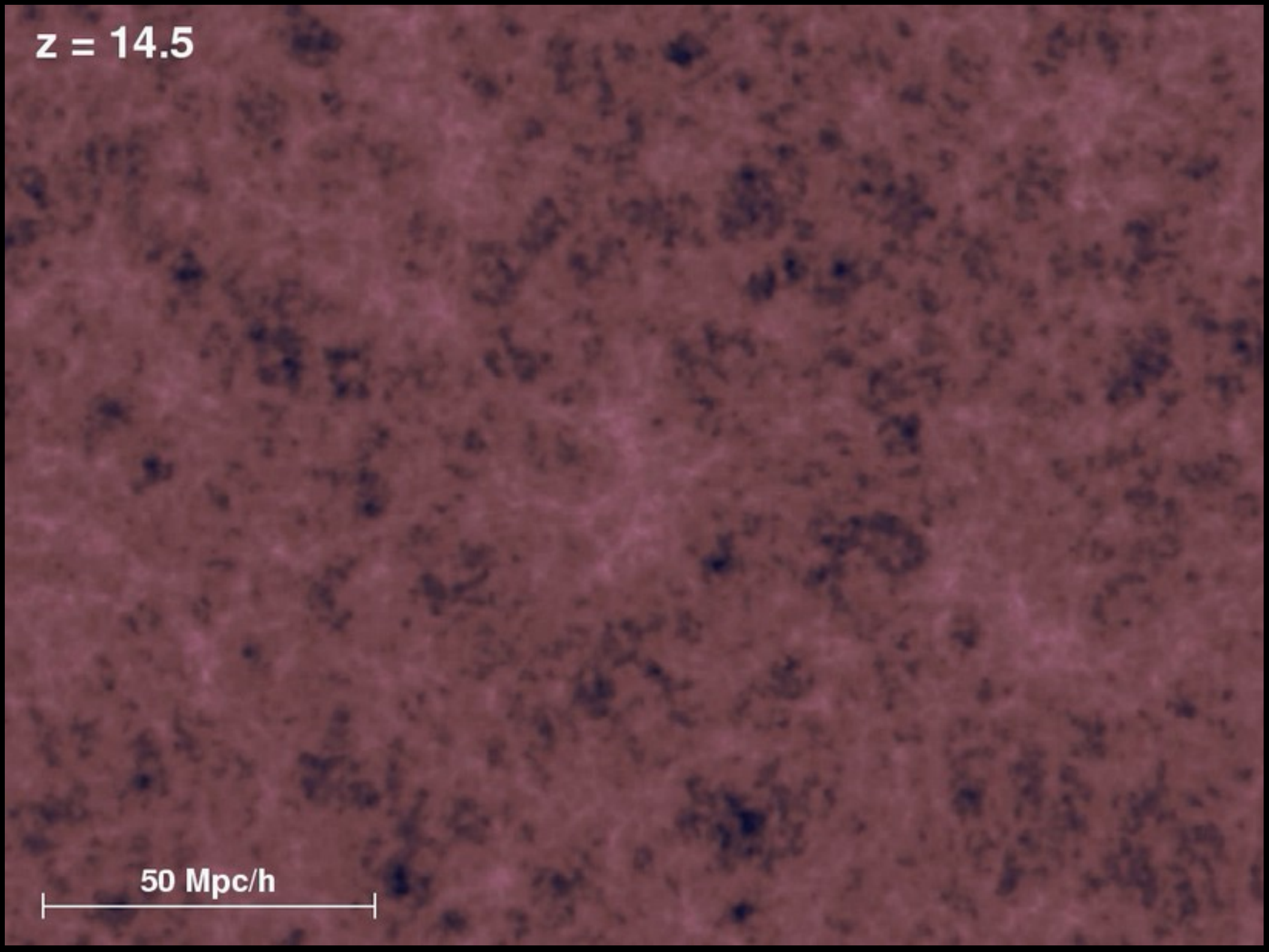
WMAP9

Five things to know about Dark Matter

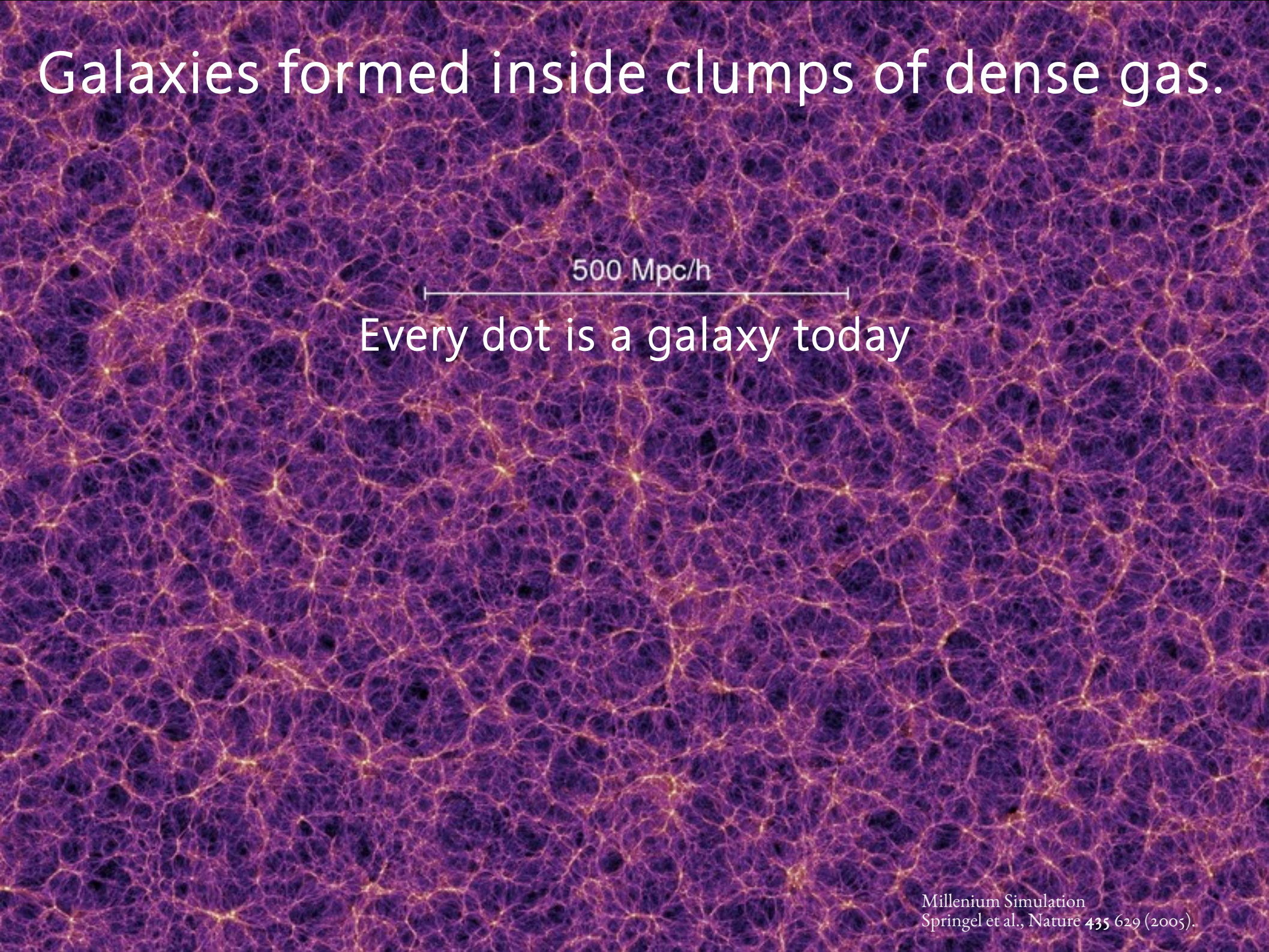
Five things to know about

Dark Matter

Builder of galaxies


z = 14.5
50 Mpc/h

Galaxies formed inside clumps of dense gas.



Millenium Simulation
Springel et al., Nature **435** 629 (2005).

Galaxies formed inside clumps of dense gas where dark matter was concentrated 14 billion years ago.

Millenium Simulation
Springel et al., Nature **435** 629 (2005).

Without dark matter, our galaxy wouldn’t have formed.

Builder of Galaxies

- Galaxies were made where there was dark matter to help concentrate gas and dust.

Without dark matter, our galaxy wouldn't have formed.

Five things to know about

Dark Matter

Builder of galaxies

Five things to know about

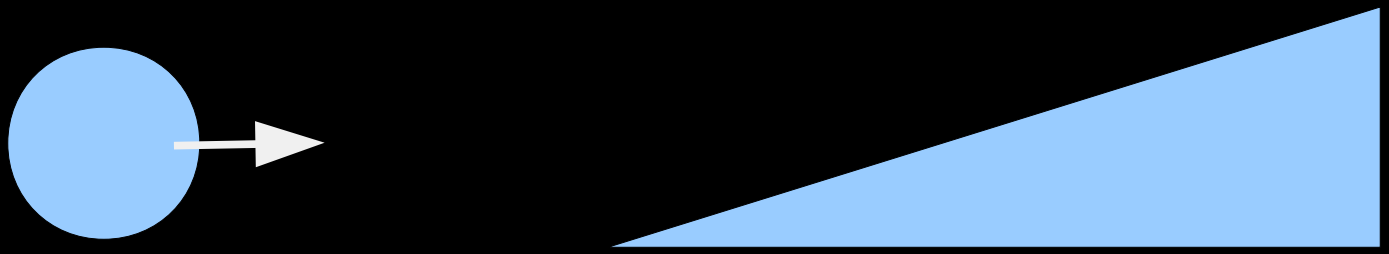
Cold Dark Matter

Builder of galaxies

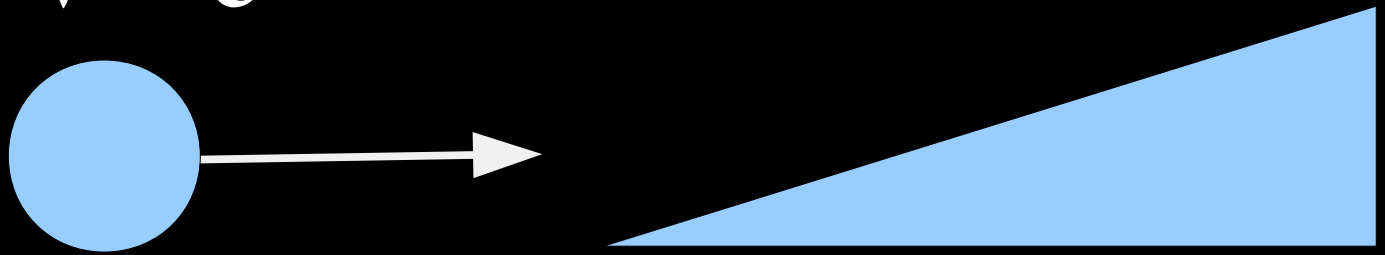
Cold

- Particles travelling slower than the speed of light

$v < c$



$v \sim c$



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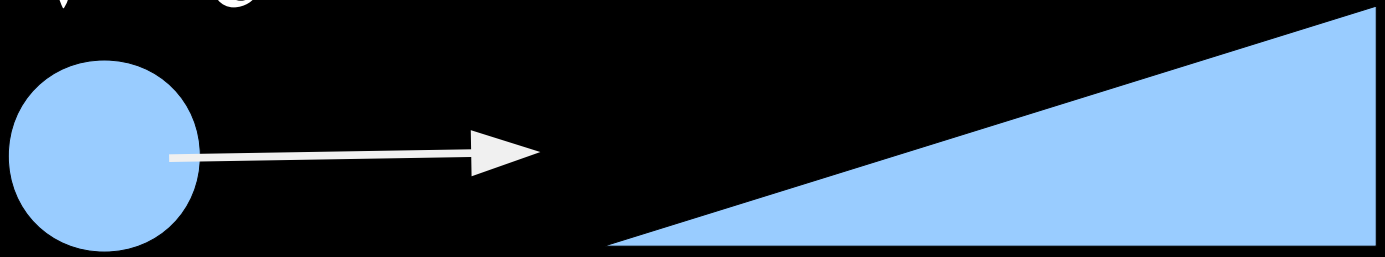
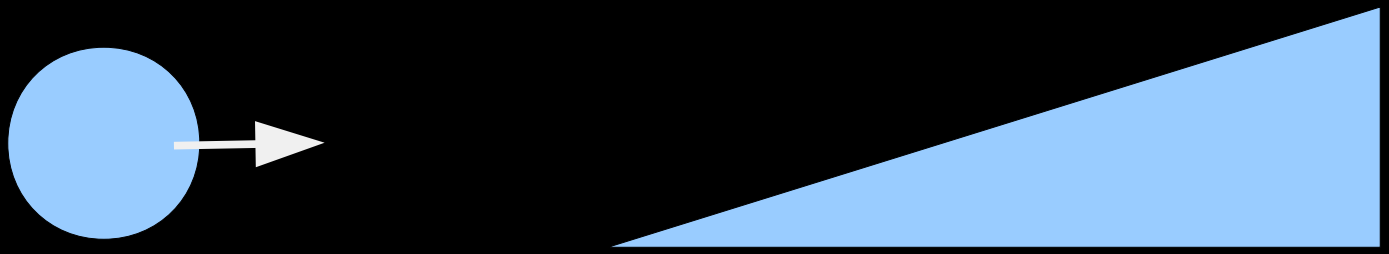
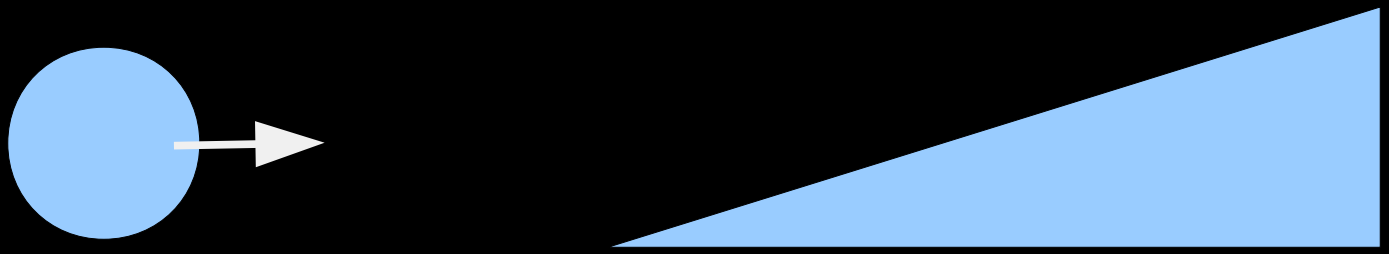


$v < c$

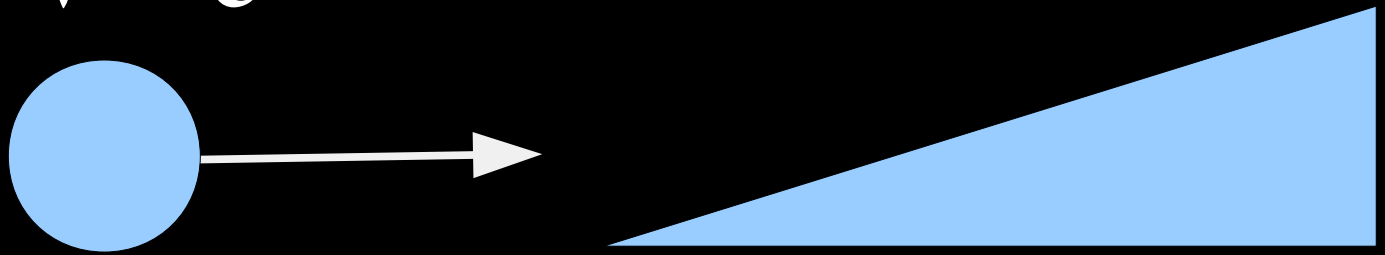


$v \sim c$

$v < c$ Loses velocity



$v \sim c$ Loses relativistic mass



Cold

- Particles travelling slower than the speed of light
  - Stays within galaxies
  - Matches the observed expansion of the universe.
- Must be a heavy particle in thermal models
  - keV/c^2 to TeV/c^2 mass

Five things to know about

Cold Dark Matter

Builder of galaxies

Five things to know about Cold Dark Matter

Builder of galaxies

We know
the standard model of particle physics

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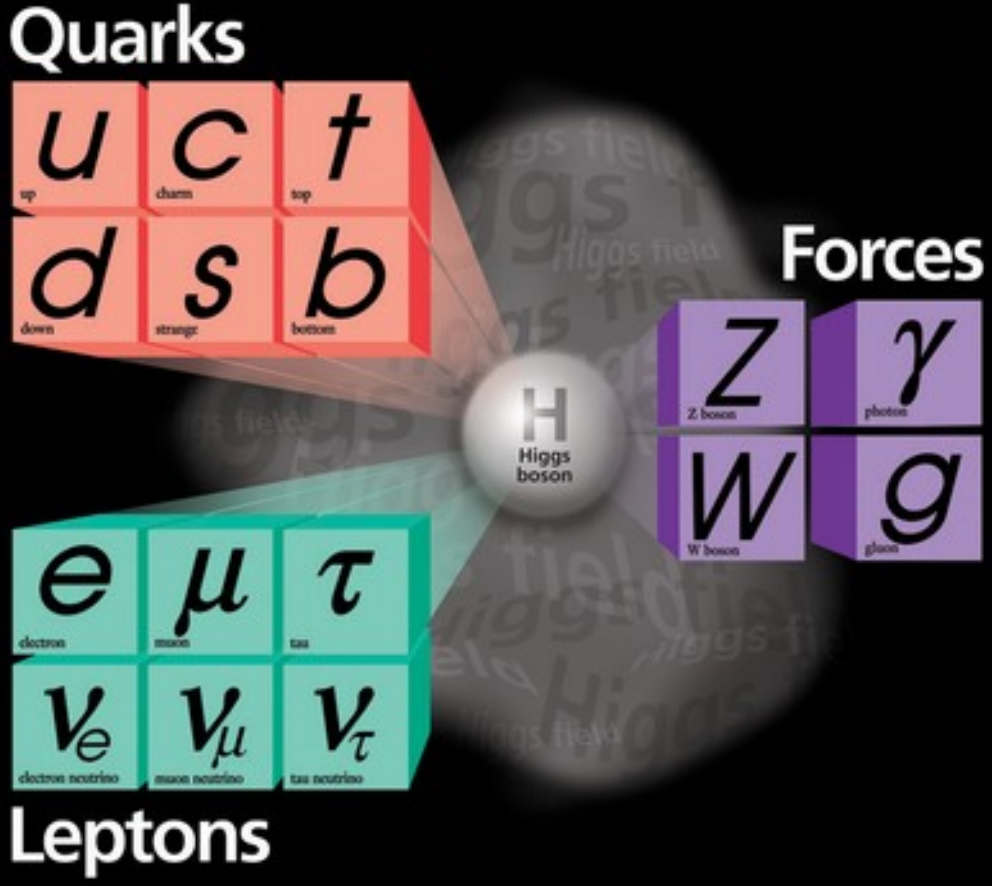
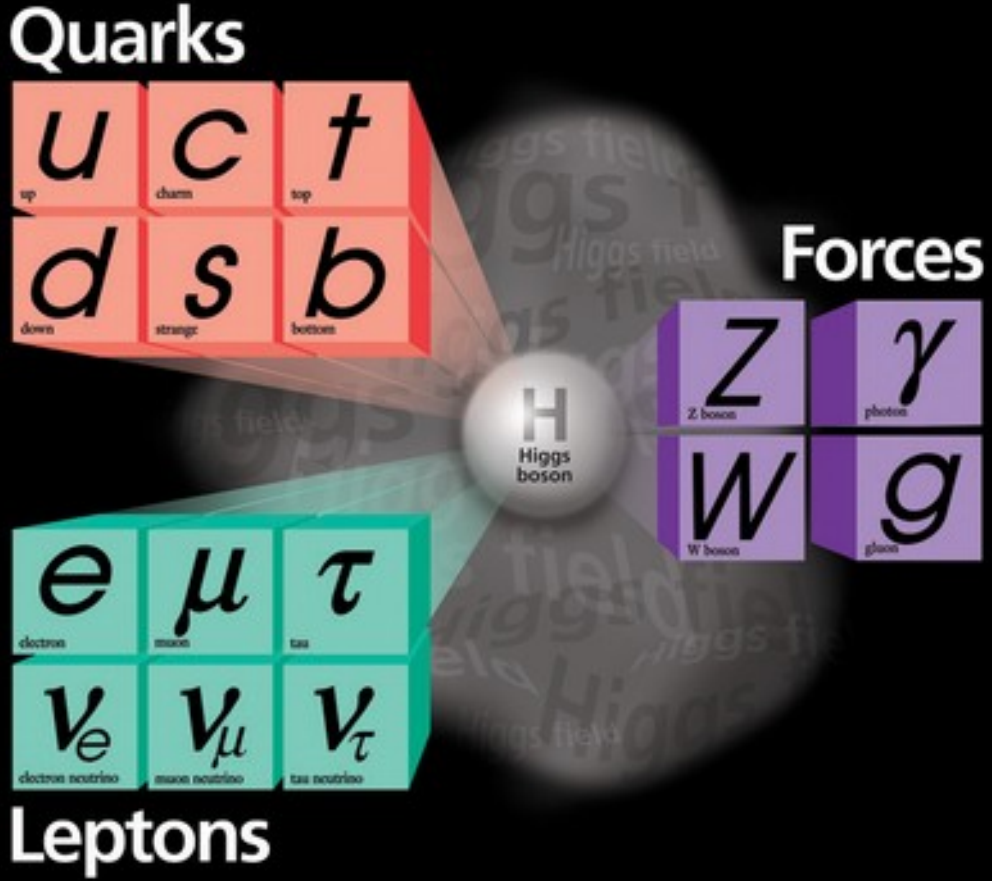
the standard model of particle physics

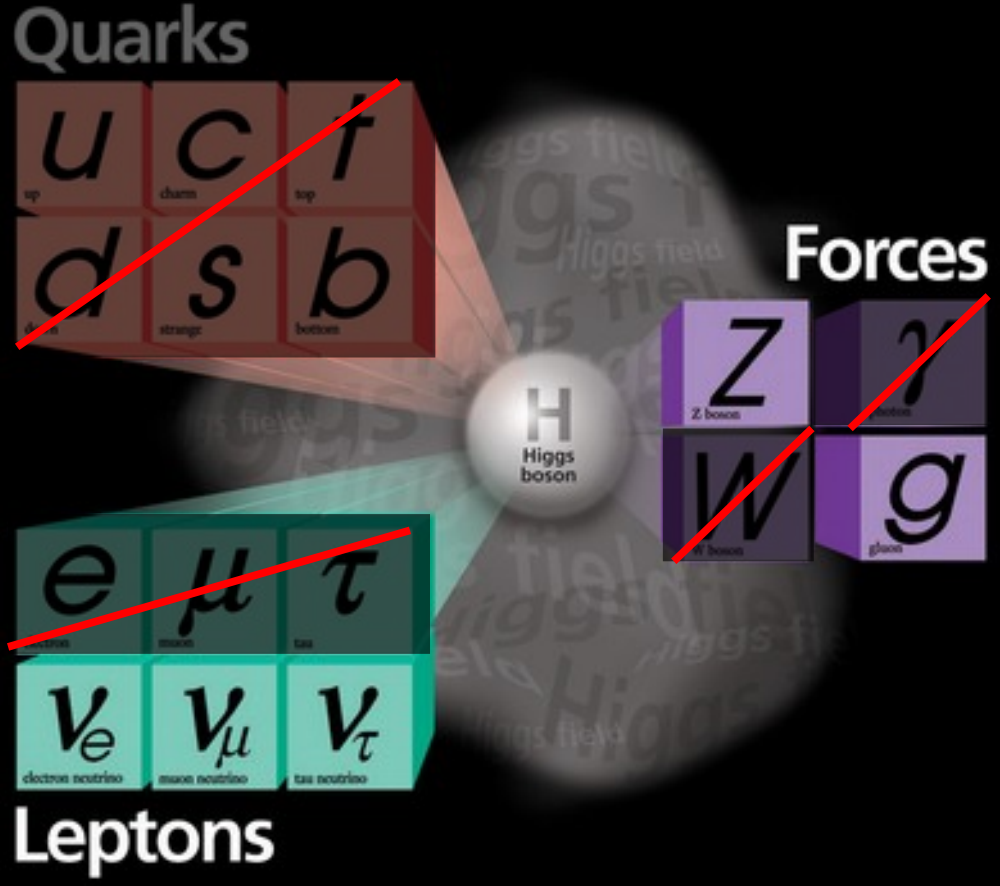


Where's dark matter?



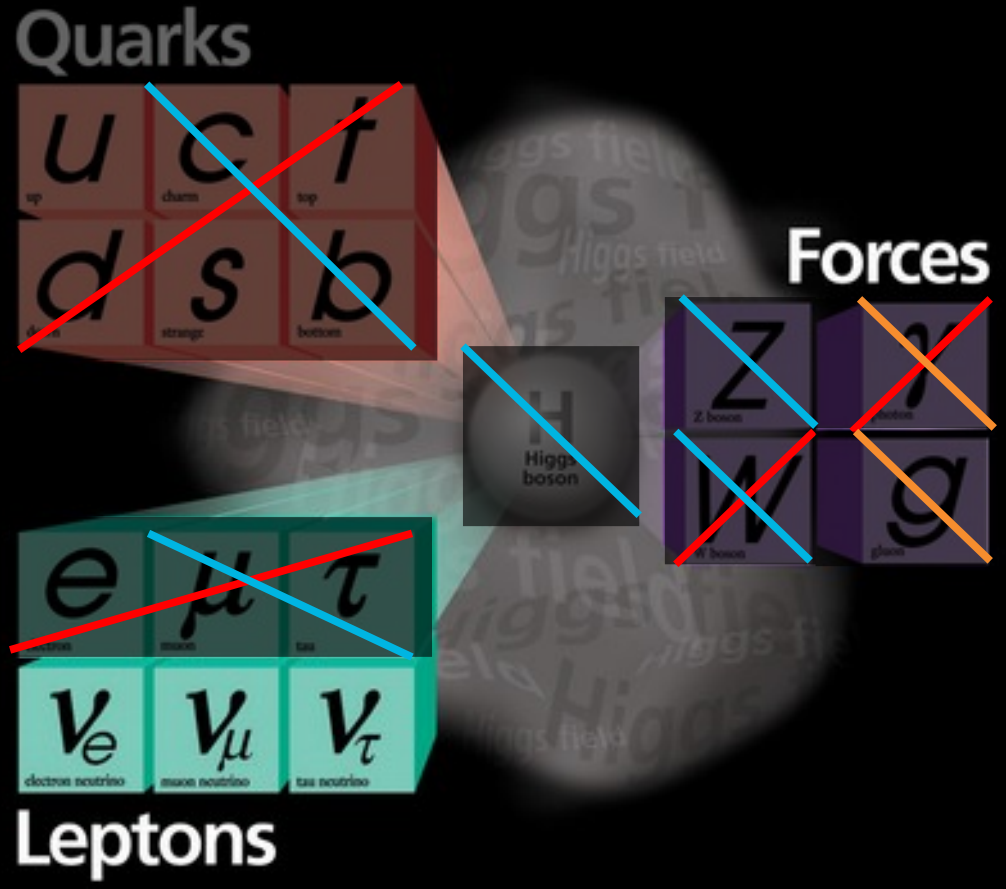
Where's dark matter?

- Dark



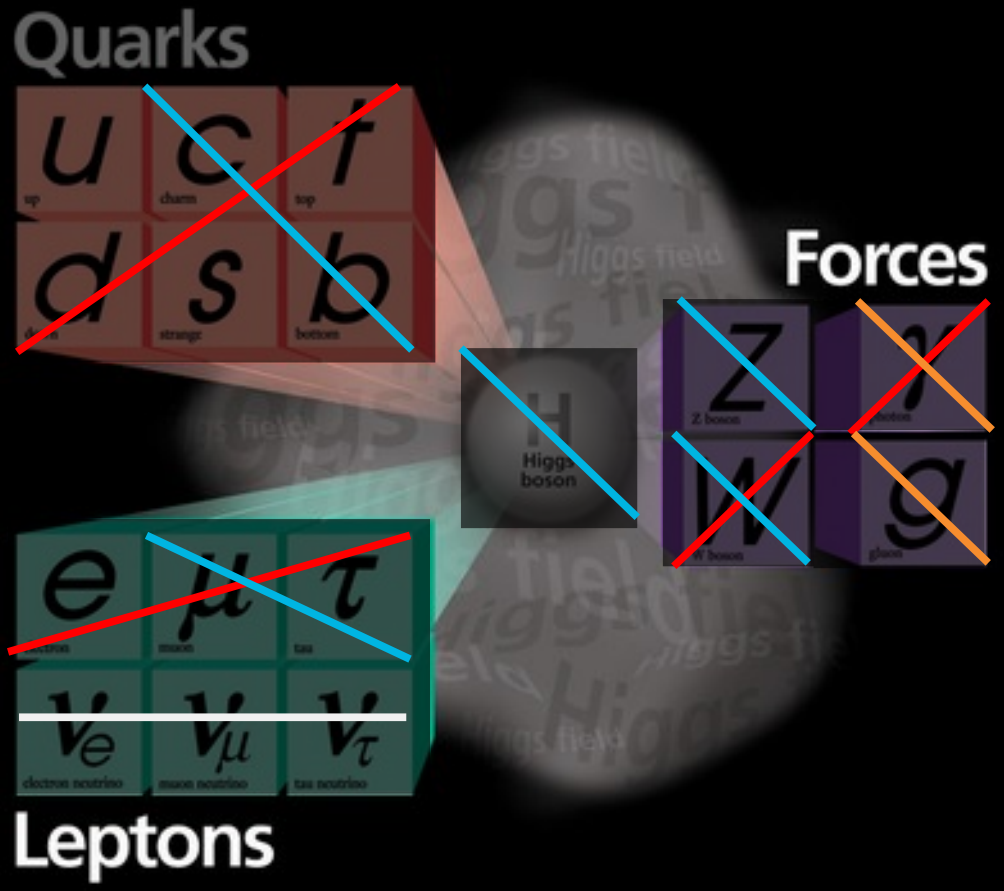
Where's dark matter?

- Dark
- Massive and stable



Where's dark matter?

- Dark
- Massive and stable
- Cold



We know
the standard model of particle physics
doesn't include dark matter.

We know
the standard model of particle physics
doesn't include dark matter.
or solutions to
- Matter/antimatter
- Strong CP problem
- Hierarchy problem

Extensions to the standard model include dark matter and solutions to

- Matter/antimatter
  - Asymmetric DM
- Strong CP problem
  - Axions
- Hierarchy problem
  - Supersymmetry

We know

Discovering dark matter interactions is key to understanding how our universe works.

Five things to know about

Cold Dark Matter

Builder of galaxies

Discovering dark matter interactions is key to understanding how our universe works.